Willow Creek Subbasin Assessment and TMDLs

Department of Environmental Quality

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1. Subbasin Assessment – Watershed Characterization

The federal Clean Water Act (CWA) requires that states and tribes restore and maintain the chemical, physical, and biological integrity of the nation's waters. States and tribes, pursuant to Section 303 of the CWA are to adopt water quality standards necessary to protect fish, shellfish, and wildlife while providing for recreation in and on the waters whenever possible. Section 303(d) of the CWA establishes requirements for states and tribes to identify and prioritize waterbodies that are water quality limited (i.e., waterbodies that do not meet water quality standards). States and tribes must periodically publish a priority list of impaired waters, currently every two years. For waters identified on this list, states and tribes must develop a total maximum daily load (TMDL) for the pollutants, set at a level to achieve water quality standards. This document addresses the waterbodies in the Willow Creek Subbasin that have been placed on what is known as the "§303(d) list."

The overall purpose of this subbasin assessment and TMDL is to characterize and document pollutant loads within the Willow Creek Subbasin. The first portion of this document, the subbasin assessment, is partitioned into four major sections: watershed characterization, water quality concerns and status, pollutant source inventory, and a summary of past and present pollution control efforts (Chapters 1 – 4). This information will then be used to develop a TMDL for each pollutant of concern for the Willow Creek Subbasin (Chapter 5).

1.1 Introduction

In 1972, Congress passed the Federal Water Pollution Control Act, more commonly called the Clean Water Act. The goal of this act was to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Water Pollution Control Federation 1987). The act and the programs it has generated have changed over the years as experience and perceptions of water quality have changed. The CWA has been amended 15 times, most significantly in 1977, 1981, and 1987. One of the goals of the 1977 amendment was protecting and managing waters to insure "swimmable and fishable" conditions. This goal, along with a 1972 goal to restore and maintain chemical, physical, and biological integrity, relates water quality with more than just chemistry.

Background

The federal government, through the U.S. Environmental Protection Agency (EPA), assumed the dominant role in defining and directing water pollution control programs across the country. The Department of Environmental Quality (DEQ) implements the CWA in Idaho, while the EPA oversees Idaho and certifies the fulfillment of CWA requirements and responsibilities.

Section 303 of the CWA requires DEQ to adopt, with EPA approval, water quality standards and to review those standards every three years. Additionally, DEQ must monitor waters to identify those not meeting water quality standards. For those waters not meeting standards, DEQ must establish TMDLs for each pollutant impairing the waters. Further, the agency must set appropriate controls to restore water quality and allow the waterbodies to meet their

designated uses. These requirements result in a list of impaired waters, called the "§303(d) list." This list describes waterbodies not meeting water quality standards. Waters identified on this list require further analysis. A subbasin assessment and TMDL provide a summary of the water quality status and allowable TMDL for waterbodies on the §303(d) list. The *Willow Creek Subbasin Assessment and TMDL* provides this summary for the currently listed waters in the Willow Creek Subbasin.

The subbasin assessment section of this report (Chapters 1 – 4) includes an evaluation and summary of the current water quality status, pollutant sources, and control actions in Willow Creek Subbasin to date. While this assessment is not a requirement of the TMDL, DEQ performs the assessment to ensure impairment listings are up to date and accurate. The TMDL is a plan to improve water quality by limiting pollutant loads. Specifically, a TMDL is an estimation of the maximum pollutant amount that can be present in a waterbody and still allow that waterbody to meet water quality standards (Water quality planning and management, 40 CFR 130). Consequently, a TMDL is waterbody- and pollutant-specific. The TMDL also includes individual pollutant allocations among various sources discharging the pollutant. The EPA considers certain unnatural conditions, such as flow alteration, a lack of flow, or habitat alteration, that are not the result of the discharge of a specific pollutant as "pollution." TMDLs are not required for waterbodies impaired by pollution, but not specific pollutants. In common usage, a TMDL also refers to the written document that contains the statement of loads and supporting analyses, often incorporating TMDLs for several waterbodies and/or pollutants within a given watershed.

Idaho's Role

Idaho adopts water quality standards to protect public health and welfare, enhance the quality of water, and protect biological integrity. A water quality standard defines the goals of a waterbody by designating the use or uses for the water, setting criteria necessary to protect those uses, and preventing degradation of water quality through antidegradation provisions.

The state may assign or designate beneficial uses for particular Idaho waterbodies to support. These beneficial uses are identified in the Idaho water quality standards and include:

- Aquatic life support – cold water, seasonal cold water, warm water, salmonid spawning, modified
- Contact recreation – primary (swimming), secondary (boating)
- Water supply – domestic, agricultural, industrial
- Wildlife habitats, aesthetics

The Idaho legislature designates uses for waterbodies. Industrial water supply, wildlife habitat, and aesthetics are designated beneficial uses for all waterbodies in the state. If a waterbody is unclassified, cold water and primary contact recreation are used as additional default designated uses when waterbodies are assessed.

A subbasin assessment entails analyzing and integrating multiple types of waterbody data such as, biological, physical/chemical, and landscape data to address several objectives:

- Determine the degree of designated beneficial use support of the waterbody (i.e., attaining or not attaining water quality standards).
- Determine the degree of achievement of biological integrity.
- Compile descriptive information about the waterbody, particularly the identity and location of pollutant sources.
- When waterbodies are not attaining water quality standards, determine the causes and extent of the impairment.

1.2 Physical and Biological Characteristics

The Willow Creek Subbasin is located in portions of Bingham, Bonneville, and Caribou counties of southeastern Idaho. The subbasin covers a geographical area of 647 square miles (mi^2), with the widest section, the middle of the basin, being approximately 25 miles (mi) wide. The basin narrows at the northern and southern ends to a width of four miles at the Ririe Reservoir and 9.5 mi in the Grays Lake area. Total basin length, from southernmost point to northernmost point, is 52 mi.

Three mountain ranges surround the subbasin: the Caribou Range is to the east, the Blackfoot Range to the west, and the Grays Range to the south. The highest peak is Caribou Mountain at 9803 feet (ft), which is located on the southeastern portion of the watershed above the headwaters of North Fork Eagle Creek, a tributary of Grays Lake. The highest peak to the west is Birch Creek Mountain at 7487 ft, where the headwaters of Birch Creek originate. To the south, Henry Peak, above headwaters for Gravel Creek, has an elevation of 8317 ft. The Grays Lake wetland complex and its source reaches reside on the southern tip of the subbasin where the elevation is approximately 7000 ft. Drainage flows towards the Ririe Reservoir, the lower end of the watershed at 5200 ft.

There are 543 stream miles in the Willow Creek Subbasin. Willow Creek is the longest stream at 57 mi; Grays Lake Outlet, a tributary of Willow Creek is the second longest at 37 mi. Headwaters for Willow Creek are located in a high elevation, spring-fed, meadow-marsh complex at approximately 6600 ft. Willow Creek proceeds through the subbasin where several tributaries merge with it to flow to the Hydrologic Unit Code (HUC) boundary, below the Ririe Reservoir at 5250 ft. The approximate valley gradient for Willow Creek, from headwaters to HUC boundary, is 24 miles.

Climate

The climate of the subbasin is classified as semiarid high desert characterized by warm to hot dry summers and long, cool winters. The climate of Idaho is primarily influenced by air masses moving inland from the Pacific Ocean (Godfrey 1999). The major source of moisture is the maritime air from the prevailing westerly winds. Convection thunderstorms during spring and summer months also contribute to precipitation in the subbasin.

Eastern Idaho tends to be more continental in character than western or northern Idaho (Godfrey 1999), resulting in a greater range between winter and summer temperatures. In summer months, rainfall, cloud cover, and relative humidity are at a minimum due to the weakening of the westerly winds, allowing continental climate conditions to prevail (Abramovich *et al*. 1998).

Table 1 lists weather stations in the vicinity of the Willow Creek Subbasin, showing the period over which the station has recorded data, the geographic location of the station, and the elevation at which the station is located.

Table 1. Weather Stations in the vicinity of the Willow Creek Subbasin.

Station Name	Station ID	Period of Record	Latitude	Longitude	Elevation (feet)
Henry, ID	104230	9/23/1971 to 10/31/1987	42°54’	111°31’	6140
Swan Valley 2E, ID	108937	7/8/1960 to 12/31/2000	43°27’	111°18’	5360
Palisades, ID	106764	7/8/1947 to 8/31/1993	43°21’	111°13’	5390
Idaho Falls 2ESE, ID	104455	5/20/1952 to 12/31/2000	43°29’	112°01’	4770
Idaho Falls 16SE, ID	104456	11/10/1955 to 12/31/2000	43°21’	111°47’	5850

Precipitation throughout the subbasin varies somewhat, as shown in Tables 2 – 6, which show monthly averages for each weather station listed in Table 1. In these tables, 1= Average Maximum Temperature (°F), 2= Average Minimum Temperature (°F), 3= Average Total Precipitation (in.), 4= Average Total Snowfall (in.), and 5= Average Snow Depth (in.).

The average annual precipitation is about 20.38 inches (in) at Henry (Table 2) near the upper end of the subbasin and is 12.25 inches at the lower end of the subbasin near Idaho Falls (Table 5). The precipitation in the area is relatively evenly distributed throughout the year with slight increases during the winter and again in May and June. Abramovich et al. (1998) indicate that southeastern Idaho is somewhat unique with these two precipitation peaks as compared to the rest of the state, which typically has one winter peak in precipitation.

The western and eastern boundaries of the subbasin probably receive the majority of the precipitation originating from orographic lifting (the rise of warm arm as it reaches a

mountain range) along the Blackfoot Mountains and the Caribou Mountains (see Figure 3). The northwestern portion of the subbasin is adjacent to the relatively flat Snake River Plain and average annual precipitation in this region is the lowest at 12.25 inches (Table 5). The Idaho Falls 16SE station (Table 6) is located within the Willow Creek subbasin in the region between Ozone and Bone. Precipitation in the Willow Creek foothills show the immediate effects of that orographic lifting with average annual precipitation up to 15.67 inches as compared to the 12 inches at Idaho Falls. Swan Valley (Table 3) and Palisades (Table 4) located on the other side of the Caribou Mountains receive average annual precipitation of 17.79 inches and 19.72 inches, respectively.

The annual average snowfall for the subbasin varies from 28.5 inches at Idaho Falls (Table 5) to 84.9 inches at Henry (Table 2) with majority of the snowfall occurring between November and March. Snow-pack tends to be greatest at the upper end of the subbasin and decreases towards the West consistent with elevation. Light snowfall begins in September in the higher elevations but the lower elevations in the subbasin generally do not receive snow until October.

Table 2. Monthly climate summary for Henry, Idaho.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1.	27.1	34.4	40.8	52	61.5	72.2	80.4	79.4	69.5	56.4	39.9	30.9	53.7
2.	3.9	7.6	14.5	22.8	33.1	39.9	43.6	41.9	34.4	26	15.6	7.6	24.2
3.	1.95	1.72	1.64	1.03	2.44	1.33	1.65	1.35	1.7	1.59	1.87	2.13	20.38
4.	17.7	15.2	10.6	4.3	1.5	0.1	0	0	0.4	2.5	14.6	17.9	84.9
5.	28	33	26	9	0	0	0	0	0	0	3	17	10

Table 3. Monthly climate summary for Swan Valley 2E, Idaho.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1.	30	35.9	44.1	54.8	65	74.7	84.1	83.2	73.5	60.3	42.1	31.2	56.6
2.	10.3	13.2	20.6	27.5	34.6	40.3	44.6	43.5	36	27.4	20.8	11.7	27.6
3.	1.56	1.07	1.22	1.58	2.55	1.65	1.30	1.27	1.51	1.25	1.54	1.29	17.79
4.	17	8.6	7.2	3.7	1.1	0.1	0	0	0.1	0.9	7.2	12	57.9
5.	10	10	4	0	0	0	0	0	0	0	1	4	3

Table 4. Monthly climate summary for Palisades, Idaho.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1.	29	34.2	42.1	53.9	65.4	74.7	84	82.1	73.1	60.2	42.4	31.5	56
2.	11.8	14.3	19.9	29	37.5	44.3	50.8	49.1	41	32.6	23.9	15.9	30.8
3.	1.94	1.63	1.52	1.56	2.16	1.94	1.12	1.29	1.49	1.37	1.76	1.94	19.72
4.	21	14.8	11	3.5	0.5	0	0	0	0	1	7.3	17.7	76.9
5.	12	14	10	1	0	0	0	0	0	0	1	5	4

Table 5. Monthly climate summary for Idaho Falls 2 ESE, Idaho.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1.	30.1	37.4	47	58.2	68.4	77.5	86.4	85.5	75.2	61.5	43.9	32	58.6
2.	12.8	17.9	24.3	31.6	39.5	46.6	52	50.2	41.5	32	23.3	14.1	32.2
3.	1.03	0.94	1.03	1.1	1.68	1.3	0.59	0.76	0.84	0.94	1	1.04	12.25
4.	8.3	5.3	3.2	0.5	0.4	0	0	0	0	0.4	3.3	7.1	28.5
5.	4	2	0	0	0	0	0	0	0	0	0	2	1

Table 6. Monthly climate summary for Idaho Falls 16SE, Idaho.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1.	31.1	35.9	42.1	52	62.2	71.2	80.3	79.1	69.5	57.8	41.5	32	54.6
2.	10.9	14.1	20.4	27.6	34.5	40.5	45.8	44.4	36.6	28.1	19.9	11.4	27.9
3.	1.57	1.17	1.36	1.41	1.82	1.47	0.89	0.85	1.14	1.09	1.46	1.44	15.67
4.	17.9	12.5	11.1	7	1.9	0.2	0	0	0.6	2.3	9.3	16.1	78.8
5.	9	9	4	0	0	0	0	0	0	0	1	5	2

Air Temperature

Maximum daily air temperatures (^{o}F) were examined at two United States Bureau of Reclamation (BOR) Pacific Northwest Region Hydromet System Data (Agrimet) stations near the Willow Creek Subbasin (http://mac1.pn.usbr.gov/agrimet/location.html). One station is in Rexburg, Idaho and the second station is in Afton, Wyoming.

For each of these two stations, seven-day moving averages were calculated for all mean daily air temperatures on record (Table 7). From these data, the maximum seven-day moving average was calculated for each year on record. Then the 90th percentile of the maximum annual seven-day averages was calculated. Finally, the number of times the 90th percentile value was exceeded by maximum daily air temperatures was determined for the entire record (minimum of ten years).

The 90th percentile of seven-day moving averages of the maximum daily air temperatures was lowest at Afton, Wyoming and highest at Rexburg, Idaho, and the differences are similar to what might be expected due to differences in elevation.

Table 7. Mean maximum daily air temperature data for two Agrimet Stations.

Rexburg, Idaho	
Period of Record	01/01/88 to 12/31/02
90th Percentile of 7-day moving average	92.9^{o}F
Number of times 90th percentile exceeded since 01/01/88	33
Afton, Wyoming	
Period of Record	01/01/83 to 12/31/02
90th Percentile of 7-day moving average	91.2^{o}F
Number of times 90th percentile exceeded since 01/01/83	22

Snow Water Content

There are four Natural Resources Conservation Service (NRCS) Snotel sites (sites outfitted with special weather stations that measure snow water content) within the vicinity of the Willow Creek Subbasin (Table 8 and Appendix A). Pine Creek Pass site is north of the Willow Creek Subbasin in the Snake River Range. The other three sites are south of the subbasin in the hills surrounding Soda Springs.

Snotel Graphs in Appendix A show snow water content at these four sites from 1988 to 2001. These graphs show daily average snow water content (heavier blue line) superimposed over the period of record's average snow water content (lighter blue line). The period of record average snow water content varies from 11 in. at Somsen Ranch to about 17 in. at Sedgewick Peak. Since 1988, data show that snow water content was below average in 1990, 1992, and 2001, very much above average in 1997, and at or above average in remaining years.

Table 8. Snotel (NRCS) Snow Water Content Monitoring sites nearest the Willow Creek Subbasin.

Site Name	Site ID	Latitude	Longitude	Elevation (feet)	Ave. Snow Water Content
Pine Creek Pass, ID	PCPI1	43.34	111.30	6720	~13 inches
Sedgewick Peak, ID	SEPI1	42.81	111.57	7900	~17 inches
Slug Creek Divide, ID	SLGI1	42.34	111.18	7225	~15 inches
Somsen Ranch, ID	SORI1	42.57	111.22	7000	~11.5 inches

Subbasin Characteristics

Subbasin characteristics relevant to this report include hydrography/hydrology, geology, topography, soils and vegetation, and fish, all of which are discussed in the following.

Hydrography/Hydrology

The Willow Creek Subbasin, a tributary basin to the Snake River, is contained within the political boundaries of three southeastern Idaho counties: Bonneville, Bingham, and Caribou (Figure 1). The Caribou Range lies to the east and the Blackfoot Mountains are along the western border of the subbasin. Drainage from the Willow Creek Subbasin proceeds northward, below the Ririe Reservoir, to the Idaho Falls subbasin (4^{th} field HUC) where it discharges into the Snake River.

Major tributaries to Willow Creek (the largest creek in the drainage) are Grays Lake Outlet, Tex Creek, Brockman Creek, Homer Creek, Crane Creek, Sellars Creek and Meadow Creek.

Within the subbasin there are two major hydrologic features, the Ririe Reservoir and Grays Lake, both of which contain water diversion/control structures. Ririe Reservoir serves as a flood control and irrigation structure on the lower reaches of the subbasin, while at the far upper reach of the subbasin lies the Grays Lake wetland complex. Water from Grays Lake is diverted to the Blackfoot Reservoir, located in the adjacent Blackfoot subbasin.

Detailed discussions of each of these two hydrologic features are presented in the following.

Grays Lake

Gray's Lake is a large wet meadow/marsh complex at the upper end of the Willow Creek Subbasin. Grays Lake historically and currently is a eutrophic lake, where an aquatic vegetation community is enriched, the lake's natural outlet is Willow Creek via Gray's Lake Outlet. Major inlets are Bridge Creek and Gravel Creek, both of which are fed by springs and runoff from nearby mountains.

Gray's Lake is named after John Grey, an Iroquois explorer and trapper (USFWS 1982). While the lake may not have been a true "lake," in that there probably was very little open water (Humphreys 1934, Simpson 2000), there was, however, abundant bullrush (*Scirpus sp*.) and other emergent vegetation (USFWS 1982, Simpson 2000).

The maximum elevation of Gray's Lake is 6390.5 ft, at which point water will either drain out the natural outlet or the artificial diversion (USFWS 1982). We suspect that the open water aspect probably varied considerably from wet years to dry years. The area fills with water after snowmelt, which in turn quickly drained away in spring. Some areas may be relatively dry meadow, whereas other areas remain spongy and wet throughout the summer. Since settlement, the area has been used for cattle grazing and hay cutting.

In 1875, Gray's Lake was surveyed and a meander line drawn to represent the high water mark (Humpherys1934, Simpson 2000). The lands adjacent to the meander line were then homesteaded.

In 1906, Brazilla Clark filed for Grays Lake water with the state engineer's office, which was granted (Humpherys 1934, Simpson 2000). Clark built a canal and diversion works known as "Clark's Cut," which took water from the southwestern corner of Gray's Lake and diverted it to Meadow Creek, a tributary to Blackfoot Reservoir. On March 20, 1907 a series of withdrawal orders were made covering lands inside the meander line. In 1908, the US Government, specifically the Indian Irrigation Service, bought Clark's interests in Gray's Lake, and the water became a part of the Fort Hall Irrigation Project (Humpherys 1934, Simpson 2000).

The US Fish and Wildlife Service (USFWS), Bureau of Sport Fisheries and Wildlife believed that the irrigation draw down and other uses of Gray's Lake were harming the wildlife values in the areas, and attempted it mitigate the dispute regarding Gray's Lake ownership (USFWS 1982). In 1964, a Memorandum of Understanding was developed between the USFWS and the Bureau of Indian Affairs (BIA) to control water levels in the lake so that USFWS could enhance waterfowl production and protect wildlife by delaying the release of water through Clark's Cut (USFWS 1982). Likewise, the Refuge Use and Cooperative Use Agreement of 1965 was established between FWS and 22 private landowners of 30 tracts surrounding Gray's Lake (USFWS 1982). In 1965 the USFWS established the Gray's Lake National Wildlife Refuge on 13,000 acres of the lakebed. This allowed usage of lands between the meander line and the refuge boundary (known as "No-Man's Land") by landowners, and maintained water levels within the refuge through the construction of levees and the

controlled release of water. In 1972, the refuge boundary was expanded to 32,825 acres (USFWS 1982). Of this acreage, 56% of the land is controlled by the USFWS.

More recently, the annual release of water from Gray's Lake continues to be a source of disagreement with the landowners and the government (Simpson 2000). Apparently, the delayed release of water from the refuge affects the quality of meadow grasses or the landowners' ability to utilize the meadow grasses. The USFWS maintains that higher water levels in spring are needed to support wildlife propagation.

Ririe Reservoir

The Ririe Reservoir is located on Willow Creek, approximately 15 miles northeast of Idaho Falls, Idaho. A dam was constructed from 1970-1977 by the Corps of Engineers to serve as an impoundment structure for the waters of Willow Creek. The reservoir has a total capacity of 100,500 acre-feet, with 10,000 acre-feet of inactive space and 80,500 acre-feet used for flood control and irrigation. The remaining 10,000 acre-feet are allocated solely for flood control operations.

In addition to flood control and irrigation, Ririe Reservoir is used for recreation such as fishing and watersports. There are four recreation areas associated with the reservoir, Juniper and Blacktail Parks support camping and day-use facilities, including a floating fishing dock and a boat-launching ramp. Benchland Park is also on the lake, but is accessible only by boat and has limited day-use facilities. Creekside Park has day-use facilities and access to Willow Creek just downstream from the dam. (http://dataweb.usbr.gov/dams/id00344.htm).

Flow Regimes

A variety of landscapes influence channel morphology within the Willow Creek Subbasin. Fluvial hydrology ranges from steep streams with low sinuosity in the mountain areas to gently sloped transport reaches in narrow valleys, open meadows, and occasionally in small canyons. Response streams tend to be entrenched in canyons. (Spatial Dynamics 2002)

Two United States Geological Survey (USGS) gauging stations (Table 9) located within the Willow Creek Subbasin have long-term trend data available. Station number 13057940 is located on Willow Creek, 0.3 miles below Tex Creek and 13.2 miles southeast of Ririe. Station number 1305800 is located further downstream on Willow Creek below Ririe Reservoir. Both stations are currently active.

Two additional USGS stations with discontinuous data are important to note because they are essential to understanding the hydrology in the upper reaches of the basin. Also listed in Table 9, these two stations are discharge points for Grays Lake: station number 13057500, Grays Lake Outlet near Herman, Idaho and station number 13057300, Grays Lake Diversion to Blackfoot Reservoir Basin near Wayan, Idaho.

Table 9. USGS Gauging Stations.

Station Number	Station Name	Location	Elevation Above Sea Level	Drainage Area (mi^2)	Period of Record
13057940	Willow Creek below Tex Creek near Ririe, ID	Latitude 43°26'30" Longitude 111°43'42"	5200	568	1977-1979, 1985–present
13058000	Willow Creek near Ririe, ID	Latitude 43°35'35" Longitude 111°46'07"	4940	627	1903-1904, 1917-1928, 1962-present
13057500	Grays Lake Outlet near Herman, ID	Latitude 43°08'05" Longitude 111°29'40"	6377		1916-1925, 1956, 1966-1970, 2002-present
13057300	Grays Lake Diversion to Blackfoot Reservoir near Wayan, ID	Latitude 43°00'21" Longitude 111°29'40"			1966-1970, 2000-present

Geology

The Willow Creek Subbasin is located in a transition zone between three physiographic provinces: the western edge of the central Rocky Mountains, the eastern margin of the Snake River Plain, and the northern extent of the Basin and Range. Geologic features common to each province are observed in the subbasin.

The subbasin is primarily underlain by a complex assortment of Paleozoic and Mesozoic sedimentary rocks in the upper portion of the subbasin and Tertiary and Quaternary igneous rocks in the lower portion. Figure 2 shows a generalized geologic map of the Willow Creek Subbasin. Both the stratigraphy and structural geology of the area strongly control the geomorphology and hydrologic features of the subbasin.

The structural geology and stratigraphy control the local groundwater flow systems within the subbasin. The Caribou Range is a regional topographic high point with a relatively high rate of precipitation. As such, the Caribou Range is the probable recharge area for much of the shallow aquifer system in the subbasin. Willow Creek Hills, located in the south-central part of the subbasin, receives less precipitation, and therefore, probably has lower recharge potential. Groundwater flow paths in the sedimentary rocks are primarily bedding plane controlled, whereas the discharge points are controlled by the geologic structure. Highly fractured, near-surface aquifers exhibit high hydraulic conductivity that decreases with depth as the fractures close. Numerous springs and seeps are present in the fractured sedimentary rocks exposed in the mountains, but most of these shallow flow systems dry up by late fall. Some springs located along range-forming extensional faults are geothermally heated, and discharge at temperatures in excess of 30 °C. The thermal springs appear to be controlled by the deep-seated extensional faults, which provide for higher geothermal gradients at depth (Ralston 1983).

Topography

The topography of the Willow Creek Subbasin results from a combination of Basin and Range type geology, higher elevation marshland, and lower elevation canyon erosion. Three prominent features of the subbasin's topography are: 1) the flat, high elevation marsh known as Gray's Lake at the southern end of the subbasin; 2) the steep-walled canyon formed by Willow Creek, a part of which is now filled by Ririe Reservoir; and 3) the parallel valleys and ridges in the center of the subbasin formed by Gray's Lake Outlet, Homer Creek, and upper Willow Creek. The east and west sides of the subbasin are lined with mountain ranges and contain the highest elevations and, in general, the steepest slopes (Figure 4). Elevations range from 4,900 feet to 9,700 feet, with the mean elevation equal to 6,382 feet. Slopes in and around Gray's Lake are less than 4% (Figure 4). In many of the valley areas slopes are less than 20%. Slopes increase rapidly to greater than 35% on mountain and foothill ranges. The lower Willow Creek canyon, including lower Gray's Lake Outlet and Tex Creek, are general steep sloped as well.

Soils and Vegetation

The Willow subbasin is in the Middle Rocky Mountain Province (USDA, 1984). In Idaho, this province extends from the Utah border to within a few miles of Montana, bordered on the east by Wyoming. Mean annual soil temperatures are between 0^0 C and 8^0 C (cryic soil temperature regime) for most soils in the province. Frigid soils with mean annual soil temperatures less than 8^0 C but with warmer summer soil temperatures can occupy wider mountain valleys.

Major soil orders in this province, according to USDA (1984), are mostly Mollisols (soils with organic rich surface horizon) and Alfisols (marginal moisture forest soils), with smaller areas of Inceptisols (young soils) and Histosols (organic soils).

There are about 414,200 acres within the Willow Subbasin delineation. Soils in the project area are described by generalized soil map units called STATSGO Map Units, from the **Stat**e **S**oil **G**e**o**graphic Database (USDA, 1994). The twelve STATSGO map units comprised by this acreage are shown in Figure 3, and are summarized in Table 10. It is important to note that Idaho STATSGO map units are currently undergoing revision based upon current detailed soil survey information; revised units should not be expected for at least a few years, however (Swenson 2001).

The K factor is a measure of the susceptibility of a soil to particle detachment and transport by rainfall, and this factor ranges from 0.02 to 0.64 or more (USDA, 1983, Part 603.02-(m)(1)(i) and (ii)). (The higher the value, the more susceptible the soil to erosion from precipitation, all other factors being equal.) Soil erodibility (hereafter 'K') factors are shown in the last column of Table 10, and in Figure 3.

Precipitation information (range and mean) is presented in Column 5 of Table 10. Figure 4 displays precipitation data for the subbasin by STATSGO map unit.

Column 6 of Table 10 shows average slope ranges for STATSGO map units. Figure 5 displays slope data for the subbasin by STATSGO map unit.

Figure 6 displays general landcover for the subbasin by STATSGO map unit.

Table 10. STATSGO Map Unit Summary

STATSGO Map Unit No.	Number of Delineation in Subbasin	Land Area: Acreage / Square Miles	Average Soil Depth[1] (inches)	Precipitation Range and Mean	Average Slope[2] (%)	K Factor Range
ID002	1	9,560 / 14.9	>60	23 – 29; 24.2	0 – 3	0.028 – 0.042
ID007	4	115,950 / 181.2	60	15 – 29; 23.2	4 – 13	0.028 – 0.042
ID010	1	107,150 / 167.4	50	13 – 33; 21	3 – 30	0.014 – 0.028
ID023	1	260 / 0.4	15	33 – 37; 35.6	1 – 93	0 – 0.014
ID027	4	26,410 / 41.3	22 – 32	13 – 31; 15	27 – 74	0 – 0.014
ID030	4	15,480 / 24.2	27 – 41	23 – 37; 28.9	25 – 55	0.042 – 0.056
ID031	5	41,850 / 65.4	54	13 – 19; 14.5	6 – 24	0.028 – 0.042
ID032	1	1980 / 3.1	60	15 – 17; 16.4	7 – 23	0.028 – 0.042
ID034	1	60 / 0.1	60	NA; 13	0 – 2	0.028 – 0.042?
ID427	2	65,990 / 103.1	42	19 – 35; 24	22 – 51	0.042 – 0.056
ID456	1	7920 / 12.4	14 – 38	19 – 31; 22	29 – 68	0 – 0.014
IDW	1	23,350 / 36.5	NA	ND[4]	0	NA

Footnotes:
1) Acreage weighted average upper and lower soil depths. If different, a range is given.
2) Acreage weighted average upper and lower slopes rounded to the nearest whole number.
3) Acreage weighted mean.
4) No Data.

The USDA Soil Conservation Service has conducted and published soil surveys of most of the Willow Creek Subbasin. USDA (1973) covers from Grays Lake northwest to the Bonneville County boundary. USDA (1981) covers the area northwest of the Bingham County boundary, with the exception of the Caribou National Forest (to the southeast). The soil survey of Caribou Co., covering the southernmost portion of the subbasin, is not yet published, and no mapping has been done to date around Grays Lake (Kyar 2001). The US Forest Service (USDA-FS) has published a draft Ecological Unit Inventory of the Targhee National Forest (USDA 1997), providing soils information for the Caribou Range mountains adjacent to the eastern boundary of the subbasin. Figures 7 and 8 show soil associations (hereafter called *soil associations* or *associations*) of both Bonneville and Bingham County Soil Surveys.

While there are differences between STATSGO map units and SCS Soil Survey soil associations there is a substantial degree of similarity between boundaries and concepts between the two mapping units. Correlations between STATSGO map units and soil associations found in the soil surveys are given in Table 11, which correlates STATSGO map units with Bonneville Co. Soil Survey soil associations, and Table 12, which correlates STATSGO map units with Bingham Co. Soil Survey soil associations.

Table 11. Correlation between STATSGO Map Units and Bonneville County Soil Associations.

STATSGO Map Unit	Soil Association (Number and Name)	Brief Description of USDA Soil Association
ID027	#4: Torriorthents - Cryoborolls – Rock Outcrop	Very steep, shallow to very deep, well drained soils, and rock outcrop; on sides of mountains and canyons
ID031 ID032 ID034	#5: Ririe – Potell	Gently sloping to steep, very deep, well drained soils; on loess foothills
ID007 ID010 ID427	#6: Dranyon – Paulson – Rock Outcrop	Sloping to very steep, deep and very deep, well drained soils, and Rock outcrop; on mountainsides

Table 12. Correlation between STATSGO Map Units and Bingham Area Soil Associations.

STATSGO Map Unit	Soil Association (Number and Name)	Brief Description of USDA Soil Association
ID002 ID007	#4: Robin – Lanark	Nearly level to steep, deep, medium textured soils, on loess covered uplands
ID010 & ID427	#8: Dranyon – Sessions – Nielsen	Nearly level to steep, deep and shallow, well drained, medium textured soils, on mountains and footslopes
ID030	#9: Sheege – Pavohroo	Nearly level to steep, shallow and deep, Well drained, medium textured soils, on mountains

As shown in Table 11, there are three soil associations, described in the Bonneville Co. Soil Survey (USDA 1981), that occur in the Willow subbasin. The following summarizes those association descriptions.

Soil Association # 4, Torriorthents - Cryoborolls - Rock Outcrop, describes those soils making up the drainage ways of Willow Creek, Meadow Creek and Tex Creek, extending northwest towards Ririe Dam. Torriorthents are on the south and west facing canyon and mountain slopes, while cryoborolls occupy north and east facing slopes. Both soils are shallow (less than 20 inches) to very deep (greater than 60 inches) with stony surface textures. Rock outcrops consist of exposed rhyolite or basalt bedrock. Vegetation in this association includes Indian ricegrass, aspen, and big sagebrush. This soil association is used primarily for rangeland and wildlife habitat. There is a hazard of erosion noted for this association.

Soil Association # 5, Ririe – Potell, occurs in the northwest portion of the Willow subbasin in loess foothills. The association's southern boundary is just below the latitude where Tex Creek joins Bulls Fork. Both soils are very deep silt loams. This association is used primarily for dryland winter wheat and spring barley. Native vegetation can include bluebunch wheatgrass, slender wheatgrass, big sagebrush and mountain big sagebrush. Minor uses include rangeland and some sprinkle irrigated agriculture. There is a hazard of erosion noted for this association.

Soil Association # 6, Dranyon – Paulson – Rock Outcrop, an upper elevation mountainous unit, occurs in the upper middle of the Willow subbasin, just north of the Bingham and Bonneville county line. As discussed previously, this association delineation joins, and is related to, Soil Association #s 4 and 8 of the Bingham Co. Soil Survey (USDA 1973), which associations are described below. Dranyon soils are deep (40 to 60 inches) and have extremely stony silt loam surface textures. Paulson soils are very deep with a silt loam surface and heavier textures in the subsurface. Rock outcropping is exposed sandstone and shale bedrock. Vegetation in this association includes aspen, bluebunch wheatgrass, snowberry, blue wildrye, and antelope bitterbrush. Uses of this association include grazeable woodland, rangeland, and wildlife. Additional information about these Bonneville County soil associations is found in Table 13

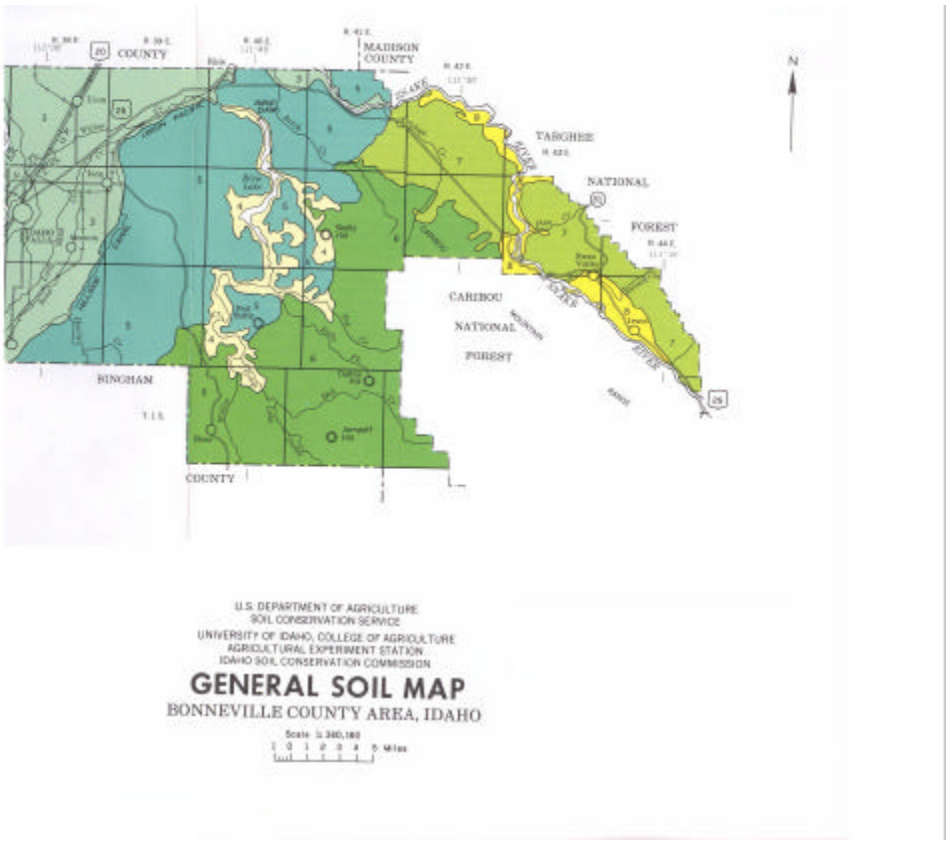

Figure 7. General Soils Map – Bonneville County.

As shown in Table 12, there are three soil associations described in the Bingham Co. Soil Survey (USDA 1973), which occur in the Willow subbasin. The following summarizes and paraphrases those association descriptions.

Soil Association # 4, Robin – Lanark, together with Soil Association # 8 (Dranyon – Sessions – Nielsen), corresponds to Bonneville Co. Soil Association # 6 (Dranyon – Paulson – Rock Outcrop). The Robin – Lanark association occurs on loess uplands. There are two major delineations of this association in the Willow subbasin: one south of Bone, broadly following Willow, Cranes, and Meadow Creeks southward, and the other broadly following Grays Lake Outlet, roughly from the confluence of Lava Creek southward to Grays Lake.

Vegetation in upland areas of this association includes Idaho fescue, streambank wheatgrass, and Colombia needlegrass. Vegetation in lowland areas of this association includes Kentucky bluegrass, timothy, and tufted hairgrass. Uses of this association include summer grazing and dryland small grain farming.

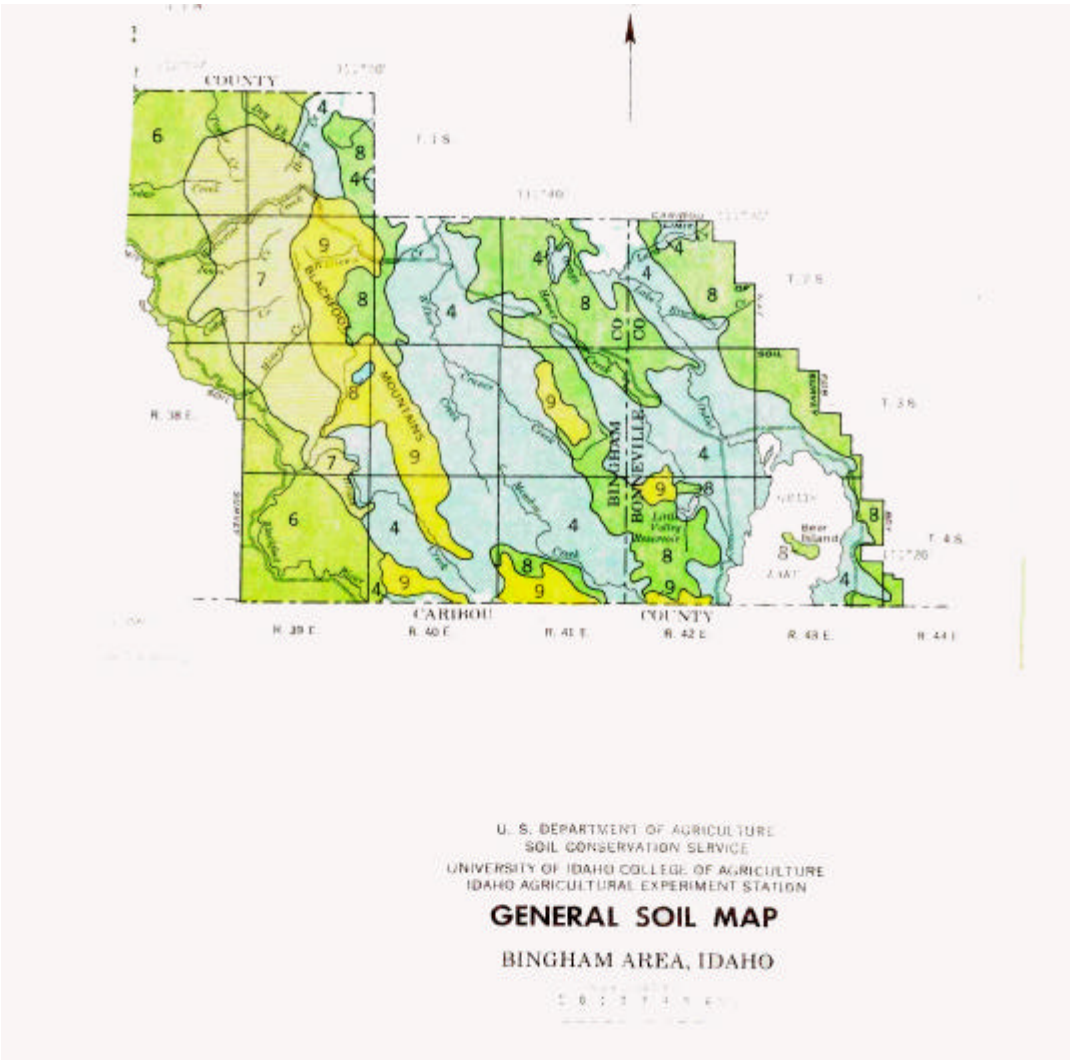

Figure 8. General Soils Map – Bingham County.

Soil Association # 8 (Dranyon – Sessions – Nielsen), together with Soil Association # 4, (Robin – Lanark), corresponds to Bonneville Co. Soil Association # 6 (Dranyon – Paulson – Rock Outcrop). The Dranyon – Sessions – Nielsen association is found at higher elevations, mostly on mountain ridges, side slopes and foot slopes. Two major delineations of this association are found in the southwest trending mountains, both to the northeast of Willow, Cranes, and Meadow Creeks, and to the northeast of Grays Lake Outlet (i.e. to the northeast of the two major delineations of the Robin – Lanark Soil Association above. Another smaller delineation is found to the west of Willow Creek, extending from northwest of Bone, southward to the west of the confluence of Cranes and Willow Creeks.

Table 13. Bonneville County Soil Associations – Additional Information.

Soil Association (Number and Name)	Percent (%) Composition	Precipitation (inches)	Average Annual Air Temperature (F^O)	Elevation (feet)	Frost Free Season (days)
#4: Torriorthents - Cryoborolls – Rock Outcrop	 45 % 35 % 15 %	8 – 18	41 - 43	4,700 – 8,000	50 – 80
#5: Ririe – Potell	 70 % 15 %	11	43	4,600 – 6,200	90
#6: Dranyon – Paulson – Rock Outcrop	 35 % 25 % 15%	20	41	6,000 – 8,000	50

Dranyon and Sessions soils are moderately deep (20 to 40 inches) and very deep respectively. Both have heavier textured subsoils (clay loam and silty clay respectively). Nielsen soils are on footslopes and are shallow with extremely stony loam soil textures. Vegetation in this association includes Idaho fescue, slender wheatgrass, and mountain brome. Woody species include aspen, Douglas fir, subalpine fir and lodgepole pine. Uses of this association include summer grazing, timber production, and dryland farming.

Soil Association # 9 (Sheege – Pavohroo) is found on the west-central part of the Willow Creek Subbasin (the eastern part of the Blackfoot mountains). Sheege soils occupy south slopes and ridge tops, and Pavohroo soils the north slopes. Sheege soils are shallow to limestone bedrock and have extremely stony loam soil textures. Pavohroo soils are very deep, having loam or silt loam surface textures, underlain by clay loam and very gravelly loam. Vegetation in this association includes Douglas fir, aspen and pinegrass on north slopes, and big sagebrush, snowberry, and western wheatgrass on south slopes. Uses of this association include summer grazing and timber production. Additional information about these Bingham County soil associations is found in Table 14.

As stated previously, USDA (1997) provides soils information for the Caribou Range mountains adjacent to the eastern boundary of the subbasin. Mapping does not extend south of the boundary between T2S and T3S (i.e. a mile north of Grays Lake). There are several Ecological Units that describe these lands, with Unit 1303 comprising the majority of the acreage. This unit is a transitional unit in foothills between cool moist shrub steppe and warm forested zone.

Table 14. Bingham County Soil Associations – Additional Information.

Soil Association (Number and Name)	Percent (%) Composition	Precipitation (inches)	Average Annual Air Temperature (F^O)	Elevation (feet)	Frost Free Season (days)
#4: Robin – Lanark	 55 % 15 %	13 – 19	36 – 43	5,000 – 7,000	80 – 100
#8: Dranyon – Sessions – Nielsen	 30 % 30 % 15 %	16 – 24	35 – 45	5,400 – 8,000	50 – 80
#9: Sheege – Pavohroo	 55 % 35 %	16 – 22	40 - 45	5,500 – 7,500	50 – 80

Major soils include Edgeway, Jumpstart, and Tophat. Edgeway is found on sideslopes; it has a shallow silt loam surface underlain by very cobbly subsoil. Jumpstart is found on north facing slopes; it is a very deep soil with silt loam surface and silty clay loam subsoil. Tophat is found on south facing slopes; it is very deep, cobbly soil with loam surface and clay loam subsoil. Vegetation includes sagebrush, aspen, and mixed conifers. Table 15 gives both common and scientific names for vegetation discussed in this report.

Table 15. Common and Scientific Names for Vegetation Mentioned in this Report.

Common Name	Scientific Name	Common Name	Scientific Name
Antelope bitterbrush	*Purshia tridentata*	Lodgepole pine	*Pinus contorta*
Aspen	*Populus tremuloides*	Mountain big sagebrush	*Artemesia tridentata Nutt ssp. (vaseyana)*
Big Sagebrush	*Artemesia tridentata*	Mountain brome	*Bromus marginatus*
Bluebunch wheatgrass	*Pseudoroegneria spicata*	Pinegrass	*Calarnagrostis rubescens*
Blue wildrye	*Elymus glaucus*	Slender wheatgrass	*Elymus trachycaulus*
Columbia needlegrass	*Achnatherum nelsonii*	Snowberry	*Symphoricarpos albus*
Douglas fir	*Pseudotsuga menziesii*	Streambank Wheatgrass	*Elymus lanceolatus*
Idaho fescue	*Festuca idahoensis*	Subalpine fir	*Abies lasiocarpa*
Indian ricegrass	*Achnatherum hymenoides*	Timothy	*Phleum pratense*
Kentucky bluegrass	*Poa pratensis*	Tufted hairgrass	*Deschampsia caespitosa*
		Western wheatgrass	*Pascopyrum smithii*

Geology and Soils Correlation

Table 16 shows tentative correlations between both geological and soil association delineations. Correlation between the subbasin geology (Figure 2) and soil delineations (Figures 3 - 8) is difficult: in most cases, generalized soil delineations in the subbasin do not directly correspond to the geological map units in Figure 2. This discrepancy between geology and soil delineations occurs, in part, because subbasin soils reflect a combination of soil forming factors in addition to the influence of parent material. In addition, some geologic map units are highly generalized and actually denote a wide variety of rock types. For example, the symbol *SR* can include limestones, dolostones, chert, shales, or sandstones, each of which may have varying resistances to weathering and erosion.

Table 16. Tentative Correlations between Geologic Map Units and Soil Associations.

Bonneville County Soil Associations			
STATSGO Map Unit	Geological Delineations	Soil Association (Number and Name)	Brief Description of USDA Soil Association
ID027	SR	#4: Torriorthents - Cryoborolls – Rock Outcrop	Very steep, shallow to very deep, well drained soils, and rock outcrop; on sides of mountains and canyons
ID031 ID032 ID034	LS; PR	#5: Ririe – Potell	Gently sloping to steep, very deep, well drained soils; on loess foothills
ID007 ID010 ID427	SR; BS	#6: Dranyon – Paulson – Rock Outcrop	Sloping to very steep, deep and very deep, well drained soils, and rock outcrop; on mountainsides
Bingham Area Soil Associations			
ID002 ID007	BS (major) SR, AL (minor)	#4: Robin – Lanark	Nearly level to steep, deep, medium textured soils, on loess covered uplands
ID010 & ID427	SR (major)	#8: Dranyon – Sessions – Nielsen	Nearly level to steep, deep and shallow, well drained, medium textured soils, on mountains and footslopes
ID030	SR (major)	#9: Sheege – Pavohroo	Nearly level to steep, shallow and deep, well drained, medium textured soils, on mountains

AL = alluvium; LS = loess; BS = basalt; PR = pyroclastic rock; SR = sedimentary rock.

Vegetation – Special Status Species

Both the Conservation Data Center (CDC) of the Idaho Department of Fish and Game and the US Fish and Wildlife Service (USFWS) maintain lists of special status plants by county. However, their lists are slightly different from each other. The CDC Special Status Plants list includes plants identified on a variety of other lists, including lists created by the Idaho

Native Plant Society, the USFWS, the Forest Service, and the BLM (see Web site: http://www2.state.id.us/fishgame/info/cdc.htm). In contrast, the USFWS list contains only those species identified by that agency as being listed under the Endangered Species Act, proposed for listing, candidates for listing, or belonging to those species of concern and watch species identified by the USFWS (Burch 2001).

The Willow Creek Subbasin straddles the border between Bonneville and Bingham Counties in Idaho, with an additional small area of Gray's Lake headwaters in Caribou County. Ute ladies'-tresses (*Spiranthes diluvialis*) is the only plant species in this subbasin listed under the Endangered Species Act, it is listed as "threatened."

Fish

There are several species of fish residing in the Willow Creek Subbasin. Representatives of the sucker family (Catostomidae), sculpin family (Cottidae), minnow family (Cyprinidae), as well as the trout and salmon family (salmonidae) are known to occur. Suckers reported in the subbasin include the Utah sucker (*Catostomus ardens*) and mountain sucker (*Catostomus platyrhynchus*). Sculpins in the subbasin include the mottled sculpin (*Cottus bairdi*) and piute sculpin (*Cottus beldingi*). Minnows reported in the subbasin include the longnose dace (*Rhinichthys cataractae*), speckled dace (*Rhinichthys osculus*), redside shiner (*Richardsonius balteatus*), and utah chub (*Gila atraria*). Species of the salmonidae reported in the subbasin include cutthroat trout (*Oncorhynchus clarki*), brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), mountain whitefish (*Prosopium williamsoni*), rainbow trout (*Oncorhynchus mykiss*) and rainbow x cutthroat hybrids. No bull trout (S*alvelinus conflentus*) occur in the Willow Creek Subbasin.

Yellowstone cutthroat trout (*Oncorhynchus clarki*) is a native species and the species of greatest concern in the subbasin. According to fish count data and local knowledge, cutthroat trout numbers have diminished significantly over the years. Problems include habitat degradation, stream flow alteration, diversions that prevent migration, and the introduction of non-native salmonids. Human activities and fish eradication and subsequent stocking programs have played a major role in the frequency and distribution of species within the watershed.

The Yellowstone cutthroat is considered a state sensitive species in Idaho and is carefully managed by the Idaho Department of Fish and Game (IDFG). In 1998 it was petitioned to become a threatened species, but after review in February 2001, the USFWS declined the petition to list the Yellowstone cutthroat under the Endangered Species Act.

Historically, IDFG has stocked fish in several streams in the Willow Creek Subbasin. Stocking records show that cutthroat, rainbow, brown, and brook trout have been planted. Within the past 25 years, Willow Creek and Ririe Reservoir are the only locations where fish stocking has occurred. IDFG ceased stocking Willow Creek in 1998 (brown trout) with the last introduction of rainbow trout in May 1996. In 2003 the Ririe Reservoir was stocked with kokanee salmon and cutthroat trout.

Beaver

The beaver (*Castor canadensis*) is an important species in the development and continued sustenance of healthy stream and riparian systems. Beavers play an important role in maintaining stable channels by preserving riparian vegetation, reducing streambank erosion, storing sediment, raising the water table, and storing water for late season release. Beaver dams are typically constructed in willow dominated, medium to low gradient, meandering, valley bottom streams (Rosgen C or B type Channels). These channels evolved over time as beaver dams trapped fine sediments that were stabilized by willows. When vegetation and beaver are removed from the system (due to trapping and/or browsing competition) dams are no longer maintained and hence are more likely to fail and release stored sediment. The increase of upstream sediment supply from grazing, cultivated agriculture, roads, urban development and timber harvest can accelerate dam failure resulting in rapid sediment release. When changes occur in the riparian plant community, the positive benefits of beavers are lost and the stream is susceptible to incising and the productive riparian areas convert to drier upland sagebrush regions as a result of lowering the water table (Caribou-Targhee 2000).

The current and historic extent and distribution of beaver in the Willow Creek Subbasin is not well documented however, long-time residents claim that beaver populations, at one time, were higher. Trapping and the reduction in suitable beaver habitat are the two principal causes of the diminished presence of beavers in the watershed. It is expected that if the riparian conditions were restored, beaver could recolonize suitable habitat and improve hydrologic conditions. Such improvements would include, (1) reduced channel degradation, (2) lower erosion rates, (3) improved late summer and drought flows, (4) increased sediment storage capacity, (5) improved water quality, (6) enhanced fish and wildlife habitat and (7) increased forage and shelter for livestock, following recovery.

Sub-watershed Characteristics

The Willow Creek Subbasin is divided into nine sub-watersheds as shown in Figure 9. Table 17 summarizes the physical attributes of fifth field HUCs based on DEQ GIS coverages. Basin length is defined as the greatest distance water flows within the sub-watershed. Basin length is useful in tabulating overall gradient of the subbasin (Spatial Dynamics 2002). The Upper Grays sub-watershed has the longest basin length at 22.61 miles. The Tex Creek sub-watershed has the shortest basin length at 12.6 miles. Refer to appendix C for unit conversions.

Table 17. Physical attributes of the 5th field HUCs within the Willow Creek Subbasin.

HUC5 Name	Area (mi^2)	Total # of Stream Miles	Elevation Range		Basin Length (mi)	Relief Ratio	Drainage Density (mi/mi^2)
			Pour Point (ft)	High Point in Watershed (ft)			
Grays Lake	134.6	74.14	6562	9515	21.89	0.0256	0.551
Homer Creek	45.14	54.96	6234	7218	19.56	0.0095	1.218
Lower Grays Outlet	61.87	67.18	5250	7218	19.51	0.0191	1.086
Lower Willow (Ozone)	41.44	22.2	5250	6562	14.37	0.0173	0.536
Middle Willow (Bone)	75.57	72.69	5250	6562	19.12	0.0130	0.962
Tex Creek	48.6	43.27	5578	7218	12.56	0.0247	0.890
Upper Grays Outlet	134.6	93.03	6234	7546	22.61	0.0110	0.691
Upper Willow	82.64	82	6234	7218	17.69	0.0105	0.992
Willow Reservoir	79.38	34.85	5250	6890	18.60	0.0167	0.439

The relief ratio has been calculated for each sub-watershed by taking the difference in elevation between the high point (maximum elevation) and the pour point (minimum elevation) in the sub-watershed and dividing that value by the length of the sub-watershed (basin length). A relief ratio of zero indicates that the land is flat and the watershed has no erosive power. The Grays Lake sub-watershed has the largest relief ratio value. It is the steepest sub-watershed and contains the highest potential erosive power.

The drainage density is calculated by dividing the total length of streams by the sub-watershed land area. This value can provide a relative measure of transport efficiency as well as a measurement of the average spatial diversity of a stream system. The Homer Creek sub-watershed has the largest drainage density, meaning it has the greatest concentration of stream miles for that given area.

A brief description of each fifth field HUC within the Willow Creek Subbasin has been provided below.

Willow Reservoir (1704020501)

The Willow Reservoir sub-watershed is positioned at the lowest elevation in the chain of sub-watersheds in the subbasin. All drainage exits the subbasin at the HUC boundary at approximately 5200 feet in elevation, just below the Ririe Reservoir on Willow Creek. Willow Creek then proceeds into the Idaho Falls subbasin where it subsequently drains into the Snake River.

This sub-watershed contains Willow Creek (SK001) and all of the unnamed ephemeral streams that drain into it below the Ririe Reservoir (SK002). The Blacktail Creek (SK003) and Meadow Creek (SK032) drainages are tributary systems of the Ririe Reservoir, with Blacktail Creek draining from the west and Meadow Creek from the east.

Tex Creek (1704020502)

This sub-watershed, relatively small, with an area of 48.6 mi^2, primarily contains the Tex Creek Wildlife Management Area. The Tex Creek sub-watershed contains the streams: Tex Creek, Bulls Fork Creek, Indian Fork Creek, and Pipe Creek. Indian Fork Creek drains from source to Tex Creek. Pipe Creek, the most northern stream discharges into Tex Creek (SK031). Indian Fork Creek, Pipe Creek, and Bulls Fork Creek (SK030) are all tributaries of Tex Creek.

Lower Willow (1704020509)

The Lower Willow 5^{th} field watershed, sometimes referred to as Ozone, contains Willow Creek (SK005) from the Grays Lake outlet confluence to its confluence with Tex Creek. A commonly known landmark on Willow Creek, Kepp's Crossing, is located in this drainage. Badger Creek and Rock Creek are named tributaries in this sub-watershed. Elevations in the watershed range from approximately 6,500 ft to 5,200 ft with a relief ratio around 0.0173.

Lower Grays Outlet (1704020503)

The Lower Grays sub-watershed, having an area of 61.87 mi^2, contains Grays Lake Outlet (SK017) and several of its tributaries, Cattle Creek, Hell Creek, Dan Creek and Jim Creek. The Hell Creek drainage (SK029) is the largest in this sub-watershed, with its largest tributary being Dan Creek. Jim Creek (SK019) is located in the southernmost (upper) part of the drainage. Cattle Creek (SK016) is the lowermost tributary of Grays Lake Outlet (SK019) in the drainage. Sub-watershed boundaries are from the confluence of Jim Creek with Grays Lake Outlet to Grays Lake Outlet's confluence with Willow Creek. There are over 67 stream miles in the sub-watershed and a drainage density of 1.086 mi/mi^2.

Middle Willow (1704020508)

The Middle Willow (Bone) sub-watershed covers a land area of 75.57 mi^2 and contains a total of 72.69 steam miles. Willow Creek and several of its tributaries are located in this 5^{th} field HUC. Squaw Creek (SK007), Birch Creek (SK006), Canyon Creek (SK008), Sellars Creek (SK010), Mud Creek (SK009), Horse Creek (SK015) and Long Valley Creek (SK 015) are all located here. There are two AUs assigned to Willow Creek in this sub-watershed, SK 008 in the lower area, near Canyon Creek and SK001 by Horse Creek. Sub-watershed boundaries are the Long Valley Creek-Willow Creek confluence, downstream to the Willow Creek Grays-Lake Outlet confluence.

Upper Grays Outlet (170402050)

The streams Grays Lake Outlet, Lava Creek, Sawmill Creek, Corral Creek, Brockman Creek, and Shirley Creek are located in the Upper Grays Outlet sub-watershed. Lava Creek (SK028) and Brockman Creek (SK024) drain directly into Grays Lake Outlet. Corral (SK026), Sawmill (SK027), and Shirley Creeks (SK024) drain into Brockman Creek, which ultimately drains into Grays Lake Outlet. This sub-watershed contains over 93 stream miles, making it the 5^{th} field with the largest quantity of stream miles. Elevation ranges from over 7500 feet to approximately 6200 feet and a total basin length of 22.61 miles.

Homer Creek (1704020506)

The Homer Creek sub-watershed contains the entire Homer Creek (SK018) drainage, over 45 mi^2 and 19.56 mi long. Sub-watershed boundaries are Homer Creek from headwaters to its confluence with Grays Lake Outlet.

Upper Willow (1704020507)

The Upper Willow Creek sub-watershed contains Willow Creek from its headwaters to just below the Long Valley Creek confluence. The streams contained in this sub-watershed are: Willow Creek (SK013), Buck Creek (SK012), Mill Creek (SK012), Seventy Creek (SK013) and Crane Creek (SK014). Buck, Mill, and Crane Creeks are all tributaries of Willow Creek.

Grays Lake (1704020505)

The Lower Willow sub-watershed is the fifth field HUC where the Grays Lake (SK021) wetland complex is located (eutrophic lake). This sub-watershed contains all of the source streams that drain into the wetland area. Streams in this drainage include: Little Valley Creek (SK022), Jones Creek, Gravel Creek, Bridge Creek, North Fork Eagle Creek, Clark Creek, and Willow Creek. Note: the Willow Creek that is mentioned in this sub-watershed is not the same creek as the Willow Creek in which the subbasin is named. For the purposes of this document the Willow Creek in the Grays Lake fifth field HUC will be hereafter referred to as Willow Creek2.

Geomorphic Risk

In 2002, per DEQ, Spatial Dynamics, Boise, Idaho, completed a Geomorphic Risk Assessment (GRA) on the Willow Creek Subbasin. A GRA provides a preliminary measure of erosivity within the subbasin, allowing for the evaluation of those areas of the watershed that are most susceptible to sedimentation. The GRA was conducted utilizing a geomorphic risk assessment model using Geographic Information Systems (GIS) technology. There are two primary components to the model, the potential sediment transport coefficient and the cumulative source coefficient. Both coefficients are derived from multiple geographic data sets and spatial analysis functions. The potential sediment transport coefficient expresses the watershed's geomorphic characteristics: relief ratio, drainage density, and bankfull discharge, which in turn describe the ability of a stream to carry sediment during a time of bankfull flow. Anthropogenic sediment sources and a natural sensitivity index produce the cumulative source coefficient component of the model. (Spatial Dynamics 2002)

A graphic of the sediment transport coefficient in the Willow Creek Subbasin is shown in figure 10. According to the GRA, Grays Lake Outlet and lower Willow Creek have the highest ability to carry sediment at bankfull flow. Figure 11 and 12 show the human caused sediment sources and the natural sensitivity index, the two major elements to the cumulative source coefficient component of the GRA. Some anthropogenic sediment sources are riparian road impacts and grazing, both are widely distributed throughout the subbasin.

Figure 13 shows the final GRA for the Willow Creek Subbasin. With all factors involved, the geomorphic risk is greatest along middle Grays Lake Outlet and on Willow Creek at its confluence with Grays Lake Outlet. The eastern perimeter of the watershed, the eastern portion of Grays Lake and the mid-western edge of the watershed, in the Sellars Creek and Birch Creek areas all have a relatively high geomorphic risk. The Tex Creek area and the Ririe Reservoir perimeter are concluded to have the lowest geomorphic risk in the subbasin

Stream Characteristics

Geomorphic characteristics of the streams in the Willow Creek Subbasin vary considerably. Appendix B contains a summary of the subbasin's stream characteristics collected by the DEQ Beneficial Use Reconnaissance Program (BURP). These data provide a detailed description of several stream characteristics.

Geomorphic characterization of the steam channels was achieved utilizing the Rosgen Stream Classification System, Level 1 for stream types. Rosgen type A streams are entrenched, high energy, steep gradient streams with cascades and step/pool morphology. Rosgen type B streams are moderate gradient, with riffles. Rosgen type C streams are low gradient, slightly entrenched, meandering streams with point bar development, riffle/pool morphology and a well-defined floodplain. Rosgen type D streams occur in broad valleys and are braided streams with point bar formations. Rosgen E type streams are very low gradient, found in broad valleys, and highly sinuous. Rosgen F type streams are low gradient, entrenched meandering streams with riffle/pool formations. Rosgen G type streams are moderate gradient, entrenched streams with step/pool morphology. (Rosgen 1996)

Stream order is a hierarchical system for categorizing streams based on their degree of branching. For example, a first order stream is unbranched, a second order stream is a combination of two first order streams and, two second order streams make a third order stream, etc. Stream order is determined using a 1:100,000-scale map.

Stream gradient is a measurement of the slope of the waters surface. Substrate measurements are collected via a modified Wolman Pebble Count. The width/depth ratio is the ratio of the bankfull surface to the average depth of the bankfull channel. This measurement is essential to comprehending the distribution of available energy within a channel and the capability of discharges within the channel to transport sediment. Width/depth ratios are beneficial in determining channel stability. Sinuosity is "the ratio of channel length between two points in a channel to the strait line distance between the same two points".

Figure 14 shows the location of waterbodies located in the Willow Creek Subbasin.

1.3 Cultural Characteristics

The majority of land ownership in the Willow Creek Subbasin is private. Landuse for the most part consists of grazing and dryland farming. Recreational activities are predominantly located near Grays Lake, Tex Creek, and the Ririe Reservoir.

Cattle and sheep grazing are the principal economic activities in the Willow Creek Subbasin. The Bureau of Land Management (BLM), Idaho Department of Lands (IDL), and United States Forest Service (USFS) have grazing allotments within the subbasin. The BLM has 35 allotments with a total of 4135 animal unit months (AUM), where an animal unit month is the amount of forage needed to feed an animal for a month.. The USFS has six allotments with 4210 animals, the majority being sheep. IDL grazing allotments for cattle and sheep exist on nearly 100 percent of the nearly 68,000 acres of Idaho endowment lands.

Land Use

As shown in Table 18, the primary land use category in the Willow Creek Subbasin is rangeland. 241,000 acres are allocated towards rangeland activity, accounting for 58 % of the total land use. Rangelands are located in the lower portions of the subbasin where the land has less relief and the hydrography is less compelling.

The next largest land use category is cropland at 23 %. The majority of cropland is located in the lower portion of the subbasin, in the Ririe Reservoir sub-watershed. Some land near Grays Lake is also used for crops. The largest component of cropland activity is dryland farming. Most of the forestland is located along the eastern edges of the Willow Creek Subbasin, with the headwaters of Willow Creek2 (tributary of Grays Lake), Corral Creek, Brockman Creek, Sawmill Creek, and Tex Creek on forestland. Figure 16 delineates land use activities in the Willow Creek Subbasin. See appendix C for a unit conversion chart.

Table 18. Land use in the Willow Creek Subbasin.

Land Use Category	Acres	Square mi	Square km	% of Total
Grays Lake	25,400	39.69	102.79	6
Cropland	94,825	148.16	383.74	23
Rangeland	241,940	378.03	979.10	58
Forest	55,950	87.42	226.42	13
	418,115	653.30	1,692.06	

The majority of roads within the Willow Creek Subbasin are county and private. The overwhelming majority of the roads within the basin are unpaved. The only paved road in the subbasin is the main road into the watershed from Sunnyside Road in Idaho Falls. This road (Bone Road) is paved to Bone, where the road splits into two main unpaved roads. The Long Valley Road runs southeast towards the northernmost tip of the Grays Lake wetland complex. The Blackfoot Reservoir Road runs directly south towards the Blackfoot Reservoir (Blackfoot Reservoir subbasin).

Land Ownership, Cultural Features, and Population

The Willow Creek watershed is rural, with very small towns within its boundary. Bone and Herman are located in Bonneville County, and the town of Wayan is located in Caribou County. There are no point source discharge facilities in the subbasin and the principal economic activity is agriculture. Clarks Cut Canal, off Grays Lake and the Ririe Reservoir Dam, are the two largest water diversion structures within the subbasin. Figure 16, Subbasin Cultural Features, shows county boundaries, town locations, and major water control structures in the Willow Creek drainage.

This watershed has a very low population density, with the majority of land ownership private at 57.8 % (Table 19). Most of the private land is used for agriculture, principally as rangeland and for dryland crops. The Idaho Department of Lands (IDL) manages approximately 67.8 thousand acres, with the majority leased for rangeland grazing. There are two wildlife management areas in the Willow Creek Subbasin. In the south, the U.S. Fish and Wildlife Service (USFWS) owns and manages the Grays Lake National Wildlife Refuge (31,816 acres) and in the north, the Idaho Department of Fish and Game (IDFG) owns and manages the Tex Creek Wildlife Management Area (31,895 acres). Forestland along the eastern perimeter of the subbasin belongs to the U.S. Forest Service (USFS), constituting 8.7 % of the subbasin's property ownership. Figure 17 shows the land ownership coverages for the Willow Creek Subbasin.

Table 19. Land ownership in the Willow Creek Subbasin.

Owner	Acres	Square miles	Square km	% of Total
Private	**238,171**	**372**	**964**	**57.8%**
Public				
BLM	5,696	9	23	1.4%
US Forest Service	35,686	56	144	8.7%
Bureat of India Affairs	863	1	3	0.2%
State of Idaho	67,766	106	274	16.5%
Idaho Fish & Game	31,895	50	129	7.7%
US Fish & Wildlife Service	31,816	50	129	7.7%
Subtotal	**173,722**	**271**	**703**	**42.2%**
Total	**411,893**	**644**	**1,667**	**100%**

History and Economics

The Willow Creek Subbasin has primarily been used for agricultural purposes since the late 1800's. Human use of the watershed is limited to rangeland, crop production, and recreation.

Three special features of the watershed are discussed in the following: Grays Lake National Wildlife Refuge, Tex Creek Wildlife Management Area, and the Ririe Reservoir.

The Grays Lake Wildlife Refuge (32,825 acres) is situated in "a relatively remote and sparsely populated high altitude mountain valley" (USGS 2002). The refuge was established in 1965 to protect and restore waterfowl nesting habitat. Public access to the refuge is seasonal and relatively light, limited to observation and waterfowl hunting in designated areas. Pursuant to a 1964 agreement, water levels from approximately 13,000 acres of lakebed continue to be managed by the BIA's Fort Hall Irrigation Project, as they have been since the early 1920's. Grays Lake Outlet, Grays Lake's sole original outlet, is now controlled by gates and Clark's Cut a man-made canal, installed in 1924 has diverted up to 20,000 acre feet a year of water into the Blackfoot Reservoir via Meadow Creek. (USGS 2002)

The Tex Creek Wildlife Management Area (WMA) was established in response to the loss of wildlife habitat, directly related to the construction of the Ririe and Teton Reservoirs in the early 1970's. Today, Tex Creek WMA encompasses more than 28,750 acres and is managed by the Idaho Department of Fish & Game (IDFG) for winter range for elk and mule deer and habitat for upland game birds. Land use agreements with private landowners provides additional forage for big game. In exchange, in the absence of big game, select portions of the WMA are used for livestock grazing. Public use of the land is limited to wildlife viewing, day hiking, horseback riding, overnight camping in designated sites, and seasonal big game, little game, and upland bird hunting. (IDFG 1996)

Construction on the Ririe Reservoir Dam, as mentioned in section 1.2, was completed in 1977. Since that time, the Ririe Reservoir has functioned as a structure to impound and control the waters of Willow Creek for recreation, flood control, and irrigation. The reservoir has a total capacity of 100,500 acre-feet (active 90,500).